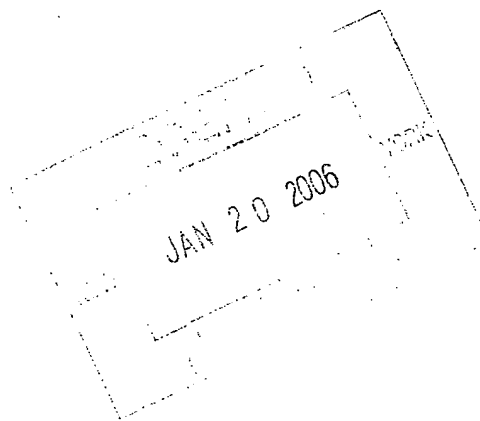**Title: APPARATUS FOR DETECTING A VEHICLE ROLLOVER   Matter: 3719   Client: 10191**
Application No: 10/523548   (P40922 USW 0 46419)

APPARATUS FOR DETECTING A VEHICLE ROLLOVER

Background Information

The present invention relates to an apparatus for detecting a vehicle rollover and a method for
5   detecting a vehicle rollover of the type set forth in the independent patent claims.

The SAE publication by W. Krantz et al.: Estimation of Side Slip Angle using Measured Tire
Forces, 2002-01-0969, SAE 2002 World Congress, March 4–7, 2002, Detroit, describes
detecting a swerving movement using tire force sensors.

Summary of the Invention

10   The apparatus and the method of the present invention for detecting a vehicle rollover having
the features of the independent patent claims have the advantage over conventional methods
that a vehicle rollover is detected using tire sensors. In particular, this permits the
determination of the plausibility of the detection of a rollover process using inertial sensors,
such as yaw-rate and acceleration sensors. In this way, an overall improvement in rollover
15   detection is achieved.

The measures and further developments recited in the dependent claims permit advantageous
improvements upon the apparatus and method, respectively, for detecting a vehicle rollover
process that are recited in the independent patent claims.

It is especially advantageous that the tire sensors are configured as pressure sensors. In most
20   cases, such pressure sensors are already present and, by analyzing the pressure ratio of the
tires on the opposite sides of the vehicle, a simple determination of the plausibility of a
rollover about the longitudinal axis of the vehicle is possible. A comparison of the pressure
ratios between the front and the back pair of tires provides a simple way of detecting a
rollover along the transverse axis — in other words, the y axis — of the vehicle. In addition
25   to or instead of this, it is possible to analyze the temperature increase of a locking tire.
Especially those tires that are subjected to high loads in a rollover will have a much higher

NY01 926811 v1

1

temperature than those that are on the side of the vehicle that lifts off the ground. Thus, here too, information indicating a vehicle rollover may be obtained by determining a ratio.

Another way to obtain information concerning the contact between the road surface and the tires might be to analyze the rotational-speed signal. Wheels that are rotating freely behave

5 differently than wheels that are locked or that are in contact with the road surface. Since the tire pressure may also be determined from the rotational-speed signal, it is possible to obtain redundant information, such that the rotational-speed measurement is possible as an alternative or instead of an absolute pressure measurement.

Brief Description of the Drawings

10 Examples of preferred embodiments of the present invention are shown in the drawings and are explained further in the following description.

The drawings show:

Figure 1   a schematic diagram of the apparatus of the invention
Figure 2   a flowchart of the method of the invention
15 Figure 3   a schematic diagram of the method of the invention,   and
Figure 4   a typical rollover process about the longitudinal axis of the vehicle.

Description

It is known that in the USA in 1998 half of all fatal single-vehicle accidents were attributable to a rollover. Vehicle rollovers constitute about 20% of all vehicle accidents.

20 Concepts for detecting a rollover process were developed in order to be able to already detect such a vehicle rollover at a very early time. This ensures that safety equipment such as seat-belt tensioners, head airbags, and roll bars may be activated promptly, thereby reducing the risk of injury. Such algorithms for detecting rollovers are based on sensor signals from inertial sensors. These sensors include, in particular, yaw-rate sensors, inclination sensors, as

25 well as acceleration sensors. The yaw-rate sensor determines the rotational velocity about the longitudinal axis of the vehicle utilizing the gyroscopic principle. The acceleration sensors also measure vehicle acceleration in the transverse and vertical direction. The yaw rate is calculated in the main algorithm. The type of rollover may be detected using the measured

values obtained from the acceleration sensors; in addition, these values are used to check plausibility. If the yaw-rate algorithm detects a rollover, the safety equipment is activated, but only if it is simultaneously enabled by the plausibility check.

One disadvantage of this approach is that the time required to trigger a response is too late in certain circumstances since, in the case of what is referred to as a soil trip, due to the locking of the vehicle's wheels on one side and to the resulting force moment, the occupants are thrown toward the window glass before the vehicle detects the rollover process.

The apparatus and the method of the present invention for detecting a vehicle rollover provide a faster process for determining the plausibility of the detection of a vehicle rollover. This earlier detection is accomplished by monitoring the condition of the vehicle on the road surface. In specific terms this means that the tires on one side of the vehicle are not in contact with the road surface in a rollover process. There are several ways to use tire sensors to monitor contact with the road surface. One way, in particular, is to monitor the tire pressure. When both tires on one side of the vehicle lose contact with the road surface, a different pressure ratio results in these tires compared to those on the other side of the vehicle that have not lost contact with the road. Likewise, information may be obtained from monitoring the relative pressure, namely the pressure at the front right and that at the rear right, and via the actual absolute pressure gradient of the pressure. In addition, the temperature may be used if the sensor supports this. In this case, it is important to know that a signifimayt temperature increase is present with locking tires. However, this effect is highly dependent on the road surface or the terrain. Nevertheless, this represents an alternative or an additional way of checking the plausibility of the detection of a rollover.

A further alternative or additional option for detecting road surface contact is to analyze the rotational-speed signals from the individual tires. As described above, wheels that may rotate freely behave differently than those wheels that are locked or are in contact with the road. Since the tire pressure may also be determined from the rotational-speed signal, it is possible in this case to generate redundant information, so that the absolute pressure measurement might not need to be performed.

A sensor used to obtain tire pressure data utilizes the following principle: A sensor mounted on the interior on the tire valve measures the tire pressure and the tire temperature at regular

intervals. The data is then transmitted to a central control unit. Preferably, the data may be transferred by wireless means. It is also theoretically possible to transfer the data inductively. In particular, passive sensors may also be used.

An analysis for detecting a vehicle rollover may be performed in various ways, including the following:

T_fl: = Tire pressure front left
T_fr: = Tire pressure front right
T_rl: = Tire pressure rear left
T_rr: = Tire pressure rear right

When the vehicle is operating normally—in other words no soil trip or rollover process is occurring—the following ratio results:

$$(T\_fl * T\_rl) / (T\_fr * T\_rr) \sim 1.0$$

Due to a shift in pressure to one side of the vehicle when, the right side of the vehicle leaves the road surface, the following ratio results:

$$(T\_fl * T\_rl) / (T\_fr * T\_rr) >> 1.0$$

Since the pressure on the right side decreases — in other words, the load on the tires decreases — and a load is applied to the tires on the left side — in other words, the pressure in the tire increases according to tendency - a disproportions results relative to the normal operation. If the tires leave the surface on the left side, this ratio approaches 0, in other words the ratios are inverted:

$$(T\_fl * T\_rl) / (T\_fr * T\_rr) << 1.0$$

The triggering time may be improved decisively by establishing a link to the yaw-rate sensor via logical operations.

Any other information or method of calculating this information may be used. For example, it is also conceivable that diagonal ratios could be analyzed.

Fig. 1 shows the apparatus of the present invention in a schematic diagram. The diagram shows four tire sensors 1 to 4, each of which is connected to a processor 5. Processor 5 is connected to a trigger-circuit controller 6, which in turn is connected to restraint means 7. For the sake of simplicity, inertial sensors, such as acceleration and yaw-rate sensors, were left

5   out here in order to focus solely on the detection of a vehicle rollover according to the invention. Here, tire sensors 1 to 4 already supply digital signals to processor 5. Alternatively, it is possible to provide external analog-digital converters to digitize the sensor signals. As described above, based on the tire-pressure ratios or the rotational-speed ratios or the temperature ratios, processor 5 determines whether one side of the vehicle or the front of the

10   vehicle or the rear of the vehicle is lifting off the road. If so, this is an indication of vehicle rollover. If this is the case, then processor 5 enables trigger device 6 so that, if the inertial sensors also detect a vehicle rollover, restraint means 7 may be activated.

Fig. 2 shows a flowchart of the method of the present invention. In method step 8, the acceleration and the yaw rates in the vehicle are determined using inertial sensors. In method

15   step 9, processor 5 checks these measured values and compares them with specified threshold values, which may be calculated adaptively. If a vehicle rollover is detected using the comparison in method step 9, then the sequence continues on to method step 10 to determine via tire sensors 1–4 whether they are also detecting a vehicle rollover. However, if it was found in method step 9 that the inertial sensors are not detecting a vehicle rollover, the

20   sequence returns to method step 8, and measuring continues. On the other hand, if a vehicle rollover is indicated based on the measured values from the inertial sensors, then in method step 11 the measured signals from tire sensors 1 to 4 are analyzed by processor 5. If, based on these measured values, processor 5 detects that they are also indicating a vehicle rollover, then the sequence skips to method step 12 and restraint means 7 are triggered by trigger-

25   circuit controller 6. However, if in method step 11 it is found that tire sensors 1–4 do not indicate a vehicle rollover, the sequence returns to method step 8, and measurement continues with the inertial sensors.

Fig. 3 shows the method of the present invention in detail using a block diagram. A yaw-rate sensor 13 sends the measured yaw rate to a filter 14. From filter 14, this filtered yaw rate is

30   received by an integrator 15 and by a comparator 19. Comparator 19 compares the value of the filtered yaw rate with a specified yaw rate calculated from blocks 17 and 18. If it is

recognized in block 19 that the filtered yaw rate is higher than this threshold, a logical 1 is sent to an AND gate 27 that is used to generate the triggering decision.

Starting from integrator 15, the integrated yaw rate, in other words the angle of rotation, is used either to generate an energy threshold or to generate a torque threshold. This is decided by a block 16 that operates a switch that switches back and forth between these two blocks 17 and 18. This is controlled by block 16 depending on a signal coming from a filter 22, this signal being the filtered acceleration signal in the vertical direction of the vehicle. This signal is determined by sensor 21, an acceleration sensor for low accelerations. Integrator 15 not only transmits the angle of rotation to generate the threshold for the rollover criterion, it also transmits it to a comparator 20, which compares the angle of rotation with an angular threshold.

If it is determined in comparator 20 that the value of the integrated angle exceeds the specified threshold, a logical 1 is sent to AND gate 27. The filtered acceleration in the vertical direction of the vehicle is sent from filter 22 not only to block 16, but also to block 26, which is responsible for establishing the plausibility of the rollover decision. The acceleration in the vehicle transverse direction is also used for this, and is transmitted from a filter 23 to plausibility 26. Filter 23 receives its signal from a sensor 22, which senses the acceleration in the vehicle transverse direction. According to the invention, a signal that is a function of the tire sensors is also passed to the plausibility function. This is provided by block 25, which handles filtering and calculations. Block 25 receives its signal from tire sensors 24, and only if plausibility function 26 also generates a logical 1, then AND gate 27 emits a logical 1, so that a triggering decision 28 will then be present.

Fig. 4 shows a typical case of a vehicle rollover about the vehicle longitudinal direction . A vehicle 33 is located on a road surface 30 and it experiences a rollover about the longitudinal direction of the vehicle. In this context, tires 29 are characterized by a pressure increase as a result of the one-sided load; while tires 31 that are off the ground are relieved of their load and therefore also experience a decrease in pressure. It is therefore clear that an indication of vehicle rollover may be provided by a simple comparison of the different pressures. However, the tire sensors do not produce a conclusive signal to indicate that a vehicle rollover is actually taking place; they may only determine that the tires have lifted off the

road surface. Therefore, the signals from the tire sensors are mainly suitable for providing a check of the plausibility of a detection of a vehicle rollover by inertial sensors.